

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



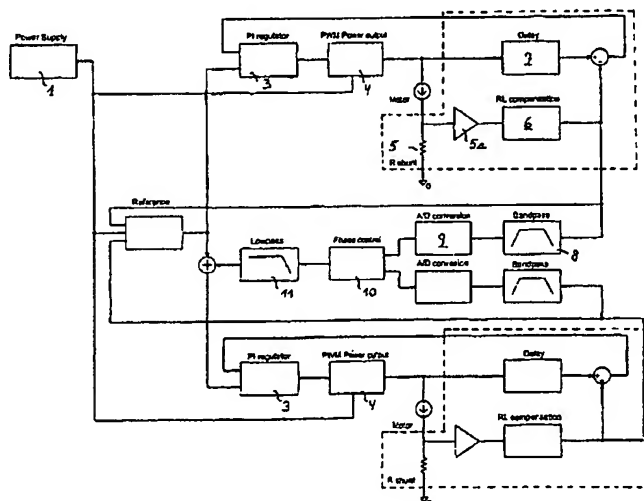
(43) International Publication Date
10 January 2002 (10.01.2002)

PCT

(10) International Publication Number
WO 02/03526 A2

- (51) International Patent Classification⁷: **H02K**
- (21) International Application Number: **PCT/DK01/00470**
- (22) International Filing Date: **5 July 2001 (05.07.2001)**
- (25) Filing Language: **English**
- (26) Publication Language: **English**
- (30) Priority Data:
PA200001048 **5 July 2000 (05.07.2000) DK**
PA200100092 **18 January 2001 (18.01.2001) DK**
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- (81) Designated States (national): **AE, AG, AL, AM, AT, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, DZ, EC, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.**
- (84) Designated States (regional): **ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).**
- Published:
— without international search report and to be republished upon receipt of that report
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: **A CONTROL FOR TWO OR MORE DC MOTORS, IN PARTICULAR ACTUATORS FOR ADJUSTMENT OF FURNITURE**



(57) Abstract: A control for DC motors, in particular actuators driven by a DC motor for adjustment of furniture, such as tables, beds, chairs, etc. includes a pseudomotor which is capable of supplying a voltage that corresponds to the motor speed on the basis of the current and voltage supplied to the motor. The voltage of the pseudomotor is supplied to an adjustable power supply, where it is compared with an internal reference voltage and adjusts the voltage difference down to the smallest possible difference between the voltage of the pseudomotor and the internal reference voltage. For greater accuracy, the control additionally includes a compensation circuit configured to evaluate a dominating frequency in the commutator noise. Thus, there is provided a simple and low cost control for parallel running of two or more actuators.

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A control for two or more DC motors, in particular actuators for adjustment of furniture

5 The present invention relates to a control for two or more DC motors, in particular actuators driven by a DC motor for adjustment of furniture, such as tables, beds, chairs, etc, wherein the motors are connected to an adjustable power supply, and wherein the control is adapted to adjust the power supply to the individual
10 motors such that the motors mutually keep the same or essentially the same speed independent of different loads on them.

Adjustment of beds and tables is performed using linear
15 actuators of the type which comprises a spindle driven by a reversible DC motor, said spindle being provided with a spindle nut which, either directly or via an extension rod, is connected with the element to be adjusted. For a height-adjustable desk carried by a single leg at each
20 side there is a linear actuator in each leg, and for beds there is one at each end for lifting the mattress frame. US 5 224 429 Haworth Inc. describes such a height adjustable desk and EP 488 552 Huntleigh Technology plc describes a height adjustable bed.

25

The prior art for operating linear actuators to obtain uniform travel thereamong is based on a direct or indirect measurement of a distance travelled and a comparison of these. A typical approach is to count the
30 number of revolutions of the spindle or another element in the transmission by an encoder or a rotary potentiometer, e.g. as described in the above US-patent. A comparison of the number of revolutions forms the basis

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for the control of the motors. It will be appreciated that a certain span of time elapses from a beginning aparallelism between the two actuators before a regulation can be carried out. These controls are
5 relatively expensive and complicated since they are based on computer controls.

The object of the invention is to provide a simple and low cost control which may be used for operating two or
10 more actuators to obtain uniform travel thereamong.

This is achieved according to the invention by a control as defined in claim 1.

15 In the present context, a pseudomotor is a circuit which electrically behaves like the DC motors concerned, and which is determined on the basis of the electrical properties of the motors.

20 The invention thus realizes that the control may be based on a pseudomotor which supplies a voltage corresponding to the speed of the motor on the basis of the energy supplied to the motor, said voltage being used for regulating the power supply.

25 It will be appreciated that the control departs from the previously mentioned controls in that the actuator does not have to travel a distance before an adjustment can take place, but that, instead, the energy transformed in
30 the motor is used as the basis, thus allowing a quicker adjustment to be made.

It is recognized that there is a certain deviation in the electrical values of the motors, which results in inaccu-

racy in the control. This is obviated in that the present control additionally comprises a compensation circuit based on the frequency of the commutator noise from the individual motors, wherein a comparison is made in the
5 compensation circuit of the frequencies from the individual motors, and in case of a deviation of the frequency from one motor relative to the frequencies of the others, the power supply to said motor or to the other motors is adjusted so that the frequencies
10 correspond. This results in a very accurate control of the motors.

It is known to control a DC motor on the basis of the frequency of the commutator noise, see e.g. DE 33 05 770
15 A1, page 8 line 11 and on, but the unique aspect of the invention is that the motors are caused to run in parallel by the pseudomotors, while the commutator frequency is used for fine adjustment of the control. Since, beforehand, the commutator frequencies from the
20 individual motors are the same or quite close to each other, the compensation circuit can respond quickly. A control exclusively based on commutator frequency will basically respond too slowly and will also be too complicated and expensive. It should be noted that a linear ac-
25 tuator has a speed, which is typically of the order of 50 mm/sec, i.e. the control must respond relatively quickly to avoid travelling non-uniformly.

In the prior art solutions, the speed depends on the construction of the actuating device, while the invention
30 adjusts speed through determination of a reference value, as the reference applies the voltage at which the motor should desirably run. Thus, a high reference value gives a high speed, and vice versa.

The present control may be implemented at low cost and without computer control. It will be appreciated that this does not rule out the possibility that the invention
5 may be used in general for the control of two or more DC motors.

The invention will be explained more fully below with reference to the accompanying drawings. In the drawings:
10

Fig. 1 shows a block diagram of an embodiment of the control according to the invention,

Fig. 2 shows an explanatory block diagram of the control
15 for further understanding of the invention, and

Fig. 3 shows a block diagram illustrating the individual motor.

20

Referring now to the block diagram in Fig. 1 the present control comprises:

- | | | |
|-----------------------------|----|-----------------------|
| 1: A power supply | 30 | 7: A delay |
| 25 2: A reference | | 8: A band-pass filter |
| 3: A PI regulator | | 9: A A/D conversion |
| 4: A PWM power output | | 10: A phase control |
| 5: A R shunt with amplifier | | 11: A low-pass filter |
| 6: A RL compensation | | |

35

1: Power supply

The power supply comprises a transformer, a bridge coupling and a rectifier capacitor. It supplies the necessary

energy to the system and is therefore the "block" that limits the performance of the system with respect to load and speed of the actuators. The voltage is unregulated, therefore is superposed by some ripple when loaded.

5

2: Reference

The reference "block" controls the system, and determines how fast the actuators must/may run. The reference circuit receives information from the two actuators and
10 the power supply, and supplies a reference voltage based on the information that enables the other circuits to stay within their regulation ranges.

3. PI regulator

15 The PI regulator regulates the speed of the individual actuator as close as possible to the voltage (speed) determined by the reference. The regulator contains a proportional part P, to keep the difference small at rapid changes in load, and an integration part I, to make
20 the difference go toward zero over an extended period of time.

4. PWM power output

The PWM power output regulates the energy to the
25 actuator. This is done by quickly connecting the power supply to and disconnecting it from the actuator. The proportion of the connection time and the disconnection time thus determines the supply of energy.

30 5: R shunt with amplifier

The resistor R converts the current running through the actuator into a voltage. This voltage is amplified in the

subsequent amplifier so that the output voltage corresponds to the voltage lying across the internal resistance in the motor plus the one lying across the shunt resistance.

5

6: RL compensation

The RL compensation compensates for current delays caused by the motor which contains a coil. This coil contributes to delaying the current relative to the voltage across the motor, which means that there will always be a time delay between voltage and speed of the motor.

10

7: Delay

To find the "internal voltage" of the motor, it is necessary to subtract the potential across the internal resistance and the coil in the motor. This is done in a subtraction circuit, but for the result to be correct it is necessary that the signals to be subtracted from each other arrive at the same time. Therefore, a delay is introduced in the direct path to the subtraction point, which corresponds to the delay existing in the path through the motor.

15

20

8: Band-pass

The band-pass filter extracts the commutator noise from the motor and removes all other noise. The bandwidth of the filter is adapted to the range of speed in which the motor will normally operate (1800-4000 r.p.m.).

25

9: A/D conversion

For these two signals to be compared, they may advantageously be converted into digital values. The values

30

may now be processed according to various logical rules,
as needed.

10: Phase control

5 Here, the two signals are compared for match/uniformity,
and as a result an instantaneous evaluation of the rela-
tion of the two signals to each other is emitted. When
the motors are running at the same speed the two signals
are totally identical, phase displaced 90° , and an
10 average value of zero is given and no adjustment is made.

11: Low-pass

Since the signal from the phase control provides instan-
taneous values and the double frequency is generated when
15 comparing the two signals, averaging of this signal is
needed. This is done by means of the low-pass filter.

With reference to the explanatory block diagrams in Fig.
2 and 3 the invention is explained in further detail. The
20 diagrams and the values indicated in the diagrams
exclusively serve to explain, but not limit the
invention. To simplify the description, this takes its
point of departure in the ohmic resistances, but the
explanation is basically the same for the other
25 electrical phenomena, such as the inductance.

The explanation is based on a height-adjustable desk hav-
ing a height-adjustable leg at each side, where the
height adjustment is performed with a linear actuator
30 driven by a DC motor.

As shown in fig. 2, the DC motors I, II of the actuators
are connected in parallel to an adjustable DC power

supply. A pseudomotor I, II is provided in the inlet to the two motors I, II. Also present is a compensation circuit having a signal input from each of the two motors I, II for commutator noise.

5

For example, if the end of the table is suddenly loaded by an additional apparatus when the tabletop is raised, the actuator concerned, i.e. motor II, will decelerate, and there will be a correspondingly greater current draw, e.g. 3A, which is recognized in the pseudomotor II, so that the voltage from the power supply to the motor will be stepped up correspondingly to 30V.

10

Fig. 3 of the drawing exemplifies an embodiment of the pseudomotor and its mode of operation. The pseudomotor is based on a shunt resistor and an amplifier whose gain is determined on the basis of the formula:

15

$$\frac{R_{\text{internal}} + R_{\text{shunt}}}{R_{\text{shunt}}}$$

20

The voltage from the amplifier is added to the voltage from the power supply. When the current draw from the motor is increased e.g. from 1A to 3A, the voltage to the motor will be increased correspondingly from 26.04V to 30.12V.

25

If, because of manufacturing tolerances, the motors do not run at exactly the same speed, the motor speeds are adjusted with the compensation circuit until a dominating commutator frequency from the two motors is within a predetermined value. In this respect one motor is picked as a master and the other as a slave to follow this.

30

In hospital beds with Trendelenburg adjustments, Trendelenburg adjustments can readily be performed e.g. by activation of one actuator or both of them, but then in their separate directions. If the bed is to be raised
5 or lowered while it is in a Trendelenburg position, the actuators are activated in parallel, i.e. in the same direction and the mattress frame is thereby displaced in parallel. The mattress frame is brought from a Trendelenburg position or an unintentional oblique po-
10 sition to a horizontal position by running it to an extreme position or by control of the actuators. Trendelenburg adjustment, tilting the mattress frame about an axis perpendicular to the mattress frame, is well known and e.g. described in US 4,425,673, see Fig. 7
15 to 10 and the relating text.

The invention is based on model motors and no direct feedback for the evaluation of the current position of the actuators.

20

As understood from the above, the invention provides a new way of controlling and regulating two or more actuators so that these run in parallel, irrespective of differences in load, without using microprocessors and
25 feedback other than that of the motor in the actuator, in other words no reed switches, hall elements or potentiometers.

Thus, the invention provides a simple and low cost paral-
30 lel control of two or more DC motors which will meet most requirements to parallel running of actuators within the

furniture industry, including nursing and hospital equipment.

P a t e n t C l a i m :

1. A control for two or more DC motors, in particular
5 actuators driven by a DC motor for adjustment of
furniture, such as tables, beds, chairs, etc, the control
is adapted to adjust the power supply to the individual
motors such that the motors mutually keep the same or
essentially the same speed independent of different loads
10 on them, c h a r a c t e r i z e d in the control
comprising a device for adjusting the power supply for
each individual motor, a pseudomotor connected to each
individual motor, said pseudomotor being constructed to
supply a voltage which corresponds to a speed of the
15 motor on the basis of the current and voltage supplied to
the motor, wherein the voltages of the pseudomotor
supplied to the power supply adjusting device are
compared with a common reference voltage, and, when one
motor experiences a greater load than the load of the
20 other motors, the reference voltage is reduced such that
the power supply to the other motors is reduced reducing
the speed of the other motors corresponding to the
reduction in speed of the one motor with the greater
load.

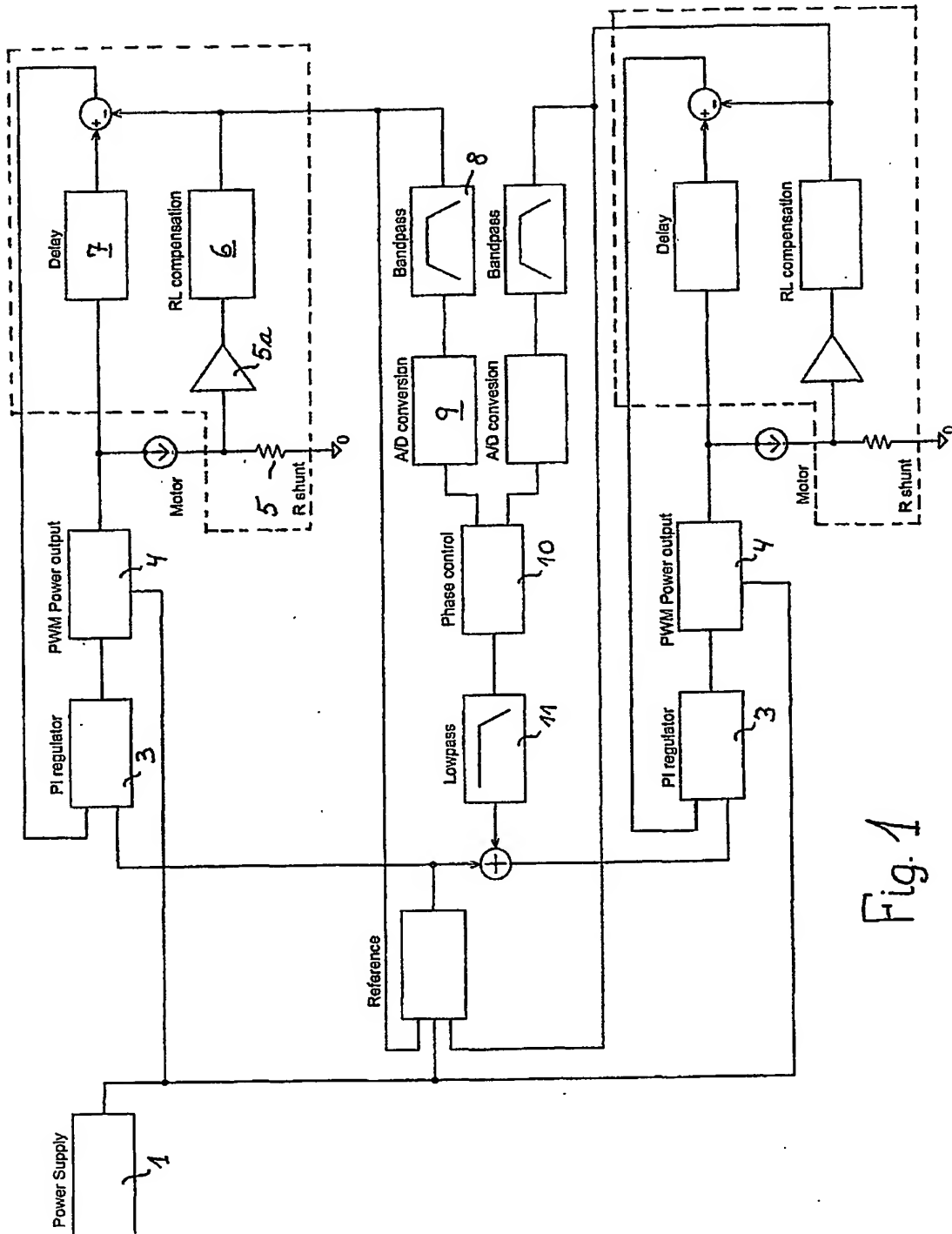
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2. A control according to claim 1, c h a r a c t e r i z
e d in that the control additionally comprises a
compensation circuit constructed according to a frequency
of commutator noise of the motors, wherein a comparison
30 is made in the compensation circuit of the frequencies of
the commutator noise of each the motors, and, in case of
a deviation of the frequency of one motor relative to the

frequencies of the other motors, the power supply to said one motor or to the other motors is adjusted so that the frequencies of the commutator noise of all the motors are within a predetermined value.

5

3. A control according to claim 2, c h a r a c t e r i z e d in that the frequency of the commutator noise is a dominating frequency



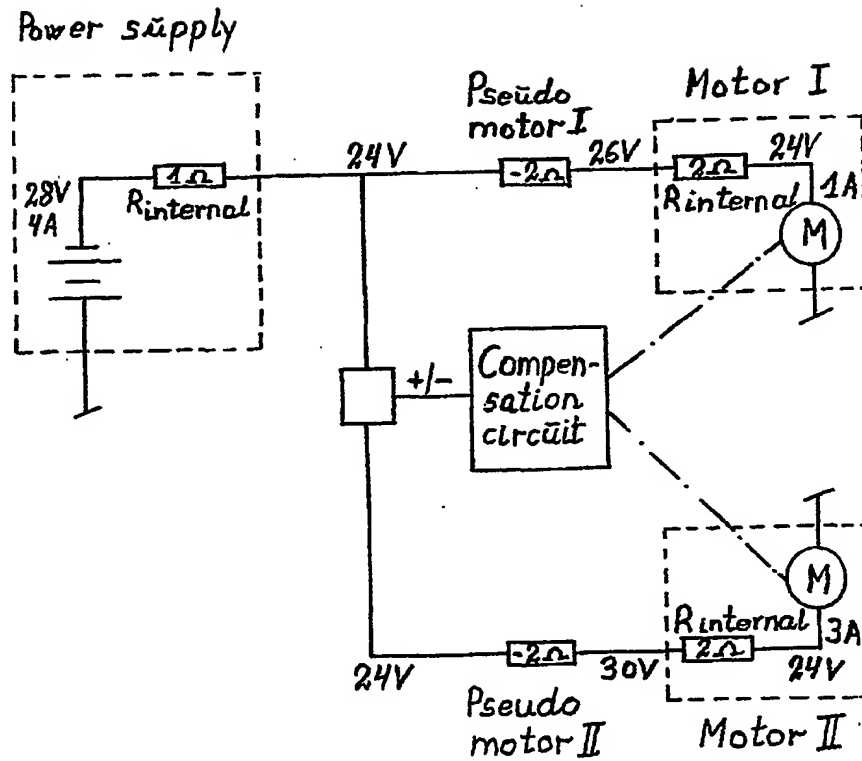


Fig. 2

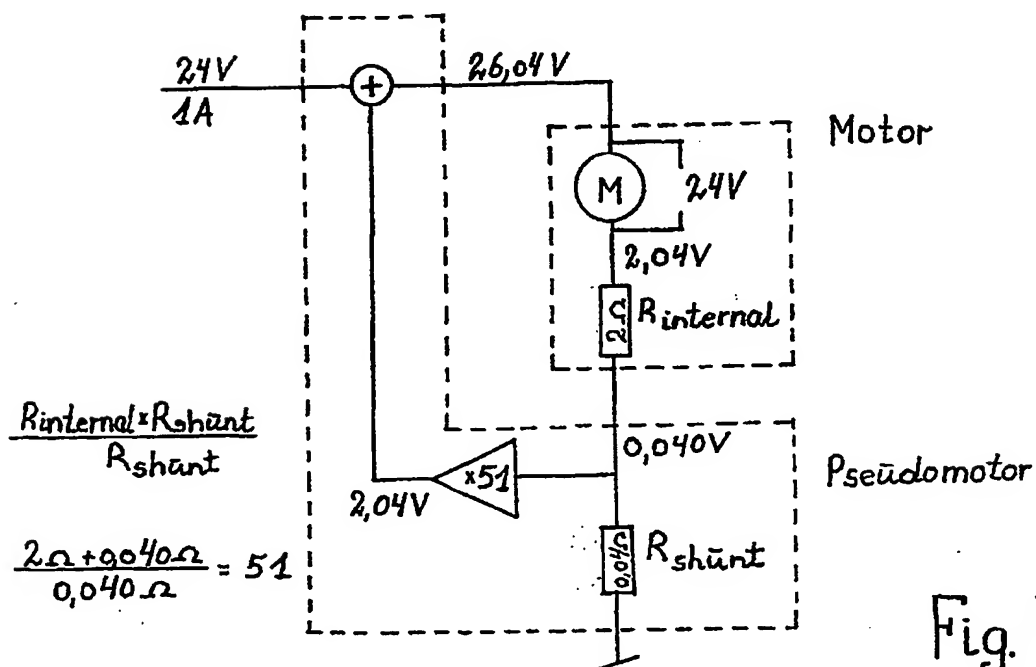


Fig. 3

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(43) International Publication Date
10 January 2002 (10.01.2002)

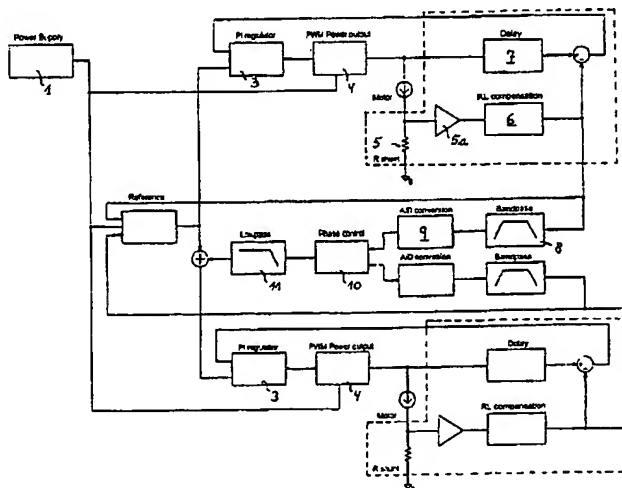
PCT

(10) International Publication Number
WO 02/003526 A3

- (51) International Patent Classification⁷: **H02P 5/50, A61G 7/18**
- (21) International Application Number: **PCT/DK01/00470**
- (22) International Filing Date: **5 July 2001 (05.07.2001)**
- (25) Filing Language: **English**
- (26) Publication Language: **English**
- (30) Priority Data:
PA200001048 5 July 2000 (05.07.2000) DK
PA200100092 18 January 2001 (18.01.2001) DK
- (71) Applicant (for all designated States except US): **LINAK A/S [DK/DK]**; Smedevænget 8, Guderup, DK-6430 Nordborg (DK).
- (81) Designated States (national): AE, AG, AL, AM, AT (utility model), AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ (utility model), CZ, DE (utility model), DE, DK (utility model), DK, DM, DZ, EC, EE (utility model), EE, ES, FI (utility model), FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
- (84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
- (72) Inventor; and
- (75) Inventor/Applicant (for US only): **BASTHOLM, Jeppe [DK/DK]**; Bækgade 3, Blans, DK-6400 Sønderborg (DK).
- (74) Agent: **LINAK A/S**; Patent Department, P.O. Box 238, DK-9100 Aalborg (DK).
- Published:
— with international search report
- (88) Date of publication of the international search report:
3 April 2003

[Continued on next page]

(54) Title: **A CONTROL FOR TWO OR MORE DC MOTORS, IN PARTICULAR ACTUATORS FOR ADJUSTMENT OF FURNITURE**



(57) Abstract: A control for DC motors, in particular actuators driven by a DC motor for adjustment of furniture, such as tables, beds, chairs, etc. includes a pseudomotor which is capable of supplying a voltage that corresponds to the motor speed on the basis of the current and voltage supplied to the motor. The voltage of the pseudomotor is supplied to an adjustable power supply, where it is compared with an internal reference voltage and adjusts the voltage difference down to the smallest possible difference between the voltage of the pseudomotor and the internal reference voltage. For greater accuracy, the control additionally includes a compensation circuit configured to evaluate a dominating frequency in the commutator noise. Thus, there is provided a simple and low cost control for parallel running of two or more actuators.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/DK 01/00470

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H02P 5/50, A61G 7/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H02P, A61G, A47P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI DATA, EPO-INTERNAL, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 4733144 A (WILHELMUS T.L. BISSELING), 22 March 1988 (22.03.88), column 1, line 42 - column 4, line 15, abstract, see the figures --	1-3
A	US 4740732 A (PETER WAY), 26 April 1988 (26.04.88), column 2, line 20 - column 3, line 18, abstract, see the figures --	1

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search

Date of mailing of the international search report

10 January 2002

14-01-2002

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INTERNATIONAL SEARCH REPORT

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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INTERNATIONAL SEARCH REPORT
Information on patent family members

06/11/01

International application No.
PCT/DK 01/00470

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